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Januchta, Kacper; Youngman, Randall E.; Goel, Ashutosh; Bauchy, Mathieu; Rzoska, Sylwester J.; Bockowski, Michal; Smedskjær, Morten Mattrup

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Correlating Densification and Crack Resistance in Sodium Aluminoborate Glasses

Kacper Januchta¹, Randall E. Youngman², Ashutosh Goel³, Mathieu Bauchy⁴, Sylwester J. Rzoska⁵, Michal

Bockowski⁵, Morten M. Smedskjaer¹

¹ *Department of Chemistry and Bioscience, Aalborg University, Aalborg, Denmark*

² *Science and Technology Division, Corning Incorporated, Corning, USA*

³ *Department of Materials Science and Engineering, Rutgers, The State University of New Jersey, USA*

⁴ *Department of Civil and Environmental Engineering, University of California, Los Angeles, USA*

⁵ *Institute of High-Pressure Physics, Polish Academy of Sciences, Warsaw, Poland*

Sodium aluminoborate glasses exhibit a high resistance to indentation cracking compared to most oxide glasses. In this work, we study seven compositions with varying Al_2O_3 and B_2O_3 contents, but fixed Na_2O content. Vickers indentation analysis shows that the nature of the network-former is decisive for the crack resistance, with Al_2O_3 -rich compositions exhibiting the highest crack resistance values in excess of 20 N. The origin of such high crack resistance is investigated by probing the response of the studied glasses to compaction in terms of their network structure and their macroscopic mechanical properties. ^{11}B MAS NMR analysis indicates that the glasses with the lower fraction of tetrahedral boron (i.e., where Na-ions are primarily associated with tetrahedral Al-units) are more prone to change their short-range order upon 1 GPa compression treatment carried out at T_g . The extent of pressure-induced structural changes is in good agreement with the extent of the accompanying increases in density, hardness, and indentation modulus. We conclude that the high crack resistance originates from the glasses' high potential to rearrange their structure when subjected to pressure. Interestingly, we observe that the volume recovery ratio (i.e., the extent of load-induced densification) exhibits a local maximum around the metaluminous composition, which does not support the observed linear compositional scaling in crack resistance. This disagreement is discussed in terms of the structural changes occurring due to the abrupt change in chemistry, and held against the positive correlation between crack resistance and compression-induced extent of densification.